

# ***Living With a Star Program***

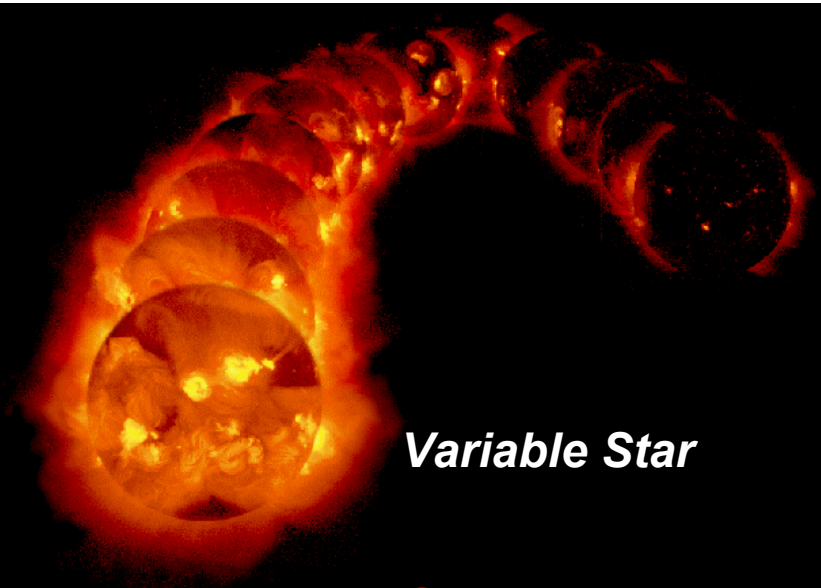


**Madhulika Guhathakurta, NASA Headquarters**  
***LWS Program Scientist***

***Report to LWSMOWG***  
***May 10, 2004***

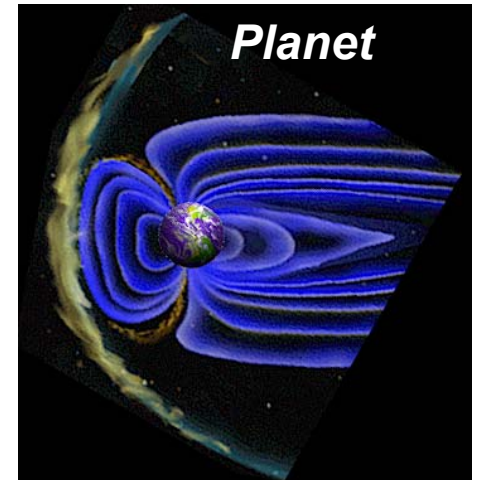
**LWS**

# ***Sun-Earth as a Connected System***

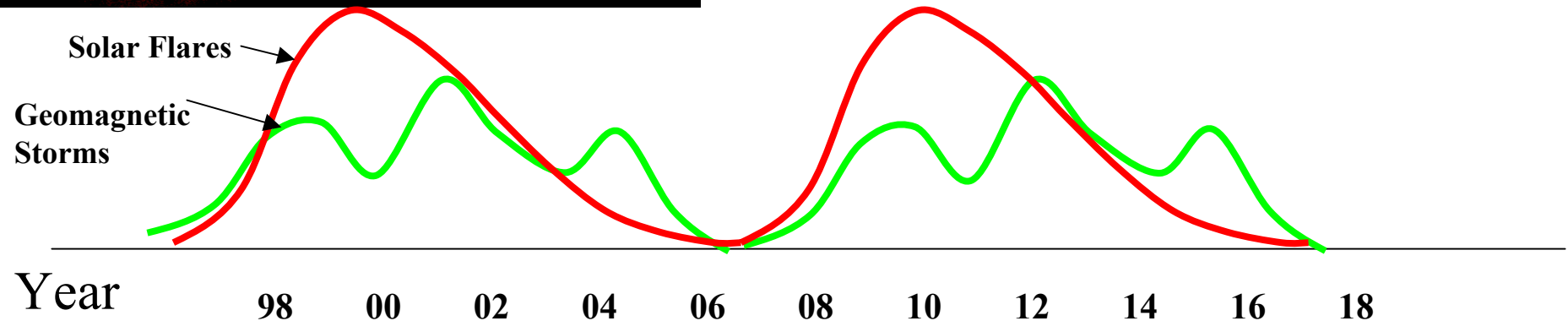


## **Varying**

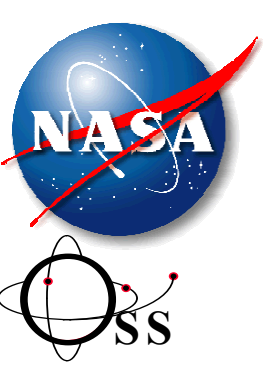
- Radiation
- Solar Wind
- Energetic Particles



Driven by 11 Year Solar Cycle



- *How and why does the Sun vary?*
- *How does the Earth respond?*
- *What are the impacts on **life and society**?*

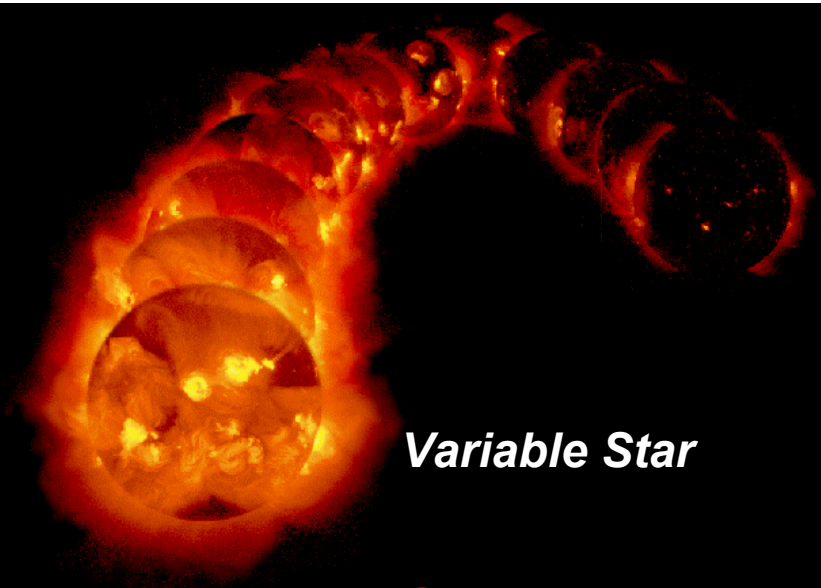


# President's Vision Goals

- Implement a sustained and affordable human and robotic program **to explore the solar system and beyond**
- Extend human presence across the solar system, starting with human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations (**enables**)
- Develop the innovative technologies, **knowledge**, and infrastructure **both to explore and support decisions** about the destinations for human exploration
- Promote **international and commercial participation in exploration to further U.S. scientific, security, and economic interests**

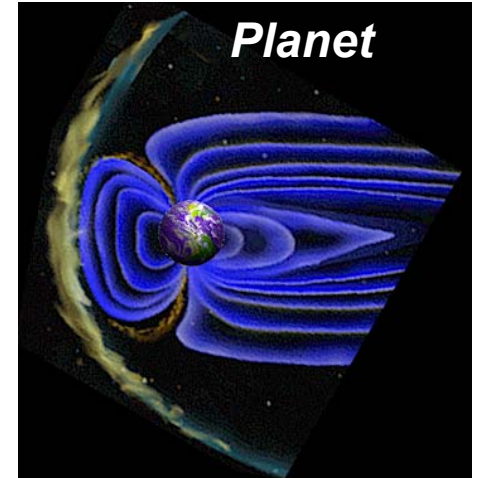
**LWS**

# **Sun-Solar System as a Connected System**

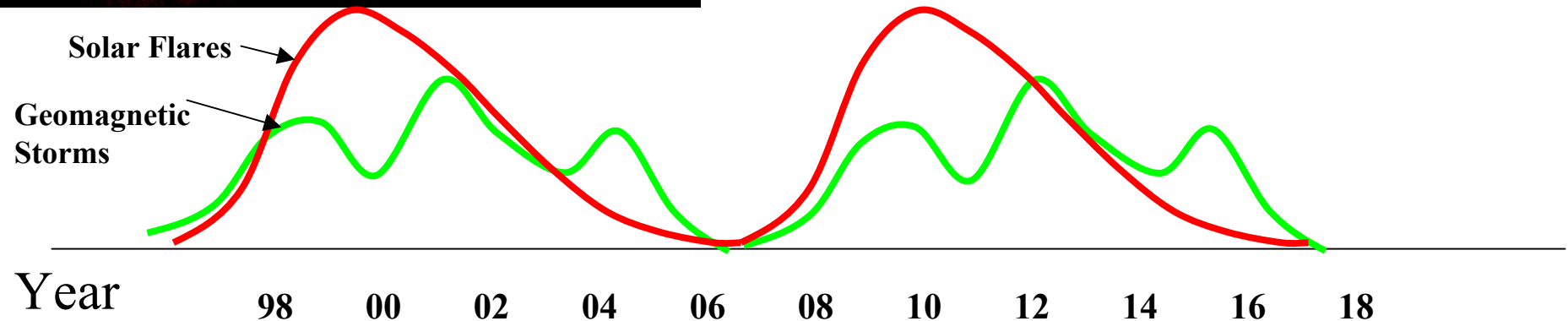


## Varying

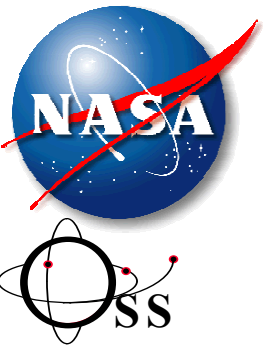
- Radiation
- Solar Wind
- Energetic Particles



Driven by 11 Year Solar Cycle

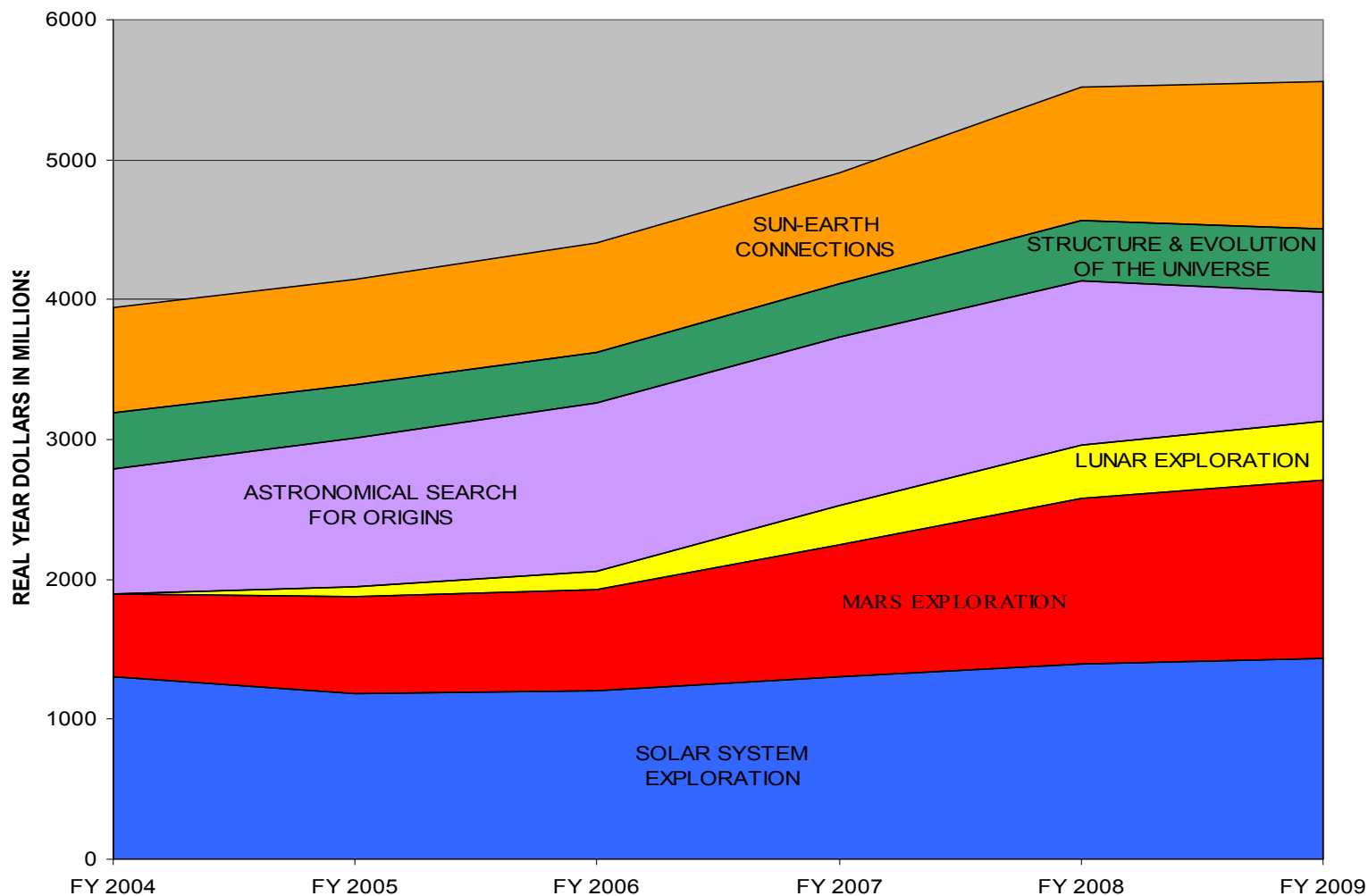


- *How and why does the Sun vary?*
- *How does the Earth **and Planets** respond?*
- *What are the impacts on **life and society**?*



# President's FY05 Budget

SPACE SCIENCE ENTERPRISE: FY 2005 PRESIDENT'S BUDGET BY THEME





## SEC: President's FY 2005 Budget (1)

### SEC: President's FY 2005 Budget

03/10/04  
7:48 AM

All funding levels are normalized to the NASA Request for FY 2005  
(which was submitted to OMB in the Fall of 2003)

When funding levels recommended in the President's FY 2005 budget (February 2004)  
differ from those requested by NASA, both levels are shown

For programs where there is no difference between the NASA request and  
the President's budget, a single line of funding is presented.

Program are grouped into categories based on the slope of their planned funding with time  
in the FY05-FY09 interval

- 1) Those for which decreasing funding was anticipated
- 2) Those for which modest (~10-25%) increases were anticipated
- 3) Those for which significant (>2x) increases were anticipated



## SEC: President's FY 2005 Budget (2)

### Programs with planned FY09/FY05 decreasing

	FY05	FY06	FY07	FY08	FY09
STEREO	1.0	0.2	0.0		
SOLAR-B	1.0	0.9	0.0		
SDO	1.0	0.8	0.7	0.3	0.1

### Programs with planned FY09/FY05 ~ 1.1 - 1.3

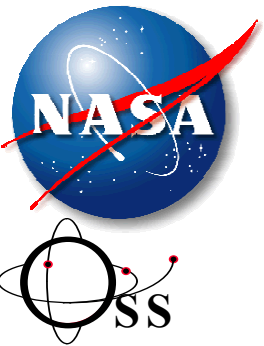
	FY05	FY06	FY07	FY08	FY09
<u>R&amp;A</u>					
NASA to OMB	1.0	1.02	1.06	1.08	1.09
President	0.98	0.98	0.98	0.98	0.98

### MO&DA

NASA to OMB	1.00	1.10	1.29	1.30	1.25
President	1.00	1.04	1.07	1.02	0.92

### Sounding Rocket Operations (Science payload funding is part of the R&A line)

NASA to OMB	1.00	1.15	1.24	1.28	1.28
President	0.95	0.95	0.95	0.95	0.95
NMP	1.00	1.08	1.06	1.10	1.16



## SEC: President's FY 2005 Budget (3)

### Programs with planned FY09/FY05 > 2

	FY05	FY06	FY07	FY08	FY09
<u>New Explorers</u>					
NASA to OMB	1.00	1.48	2.94	3.45	3.49
President	0.42	1.01	1.47	2.95	3.45
<u>New STP</u>					
NASA to OMB	1.00	2.35	2.22	2.67	2.80
President	0.22	0.42	0.56	1.43	1.43
<u>New LWS</u>					
	1.0	2.2	2.8	3.9	5.9

New Explorers = Results of ongoing SMEX selection and new AO's;  
projected AIM and THEMIS costs are covered in a separate budget line

New STP = MMS, GEC, JPO, MagCon.....

New LWS = Geospace and Sentinels

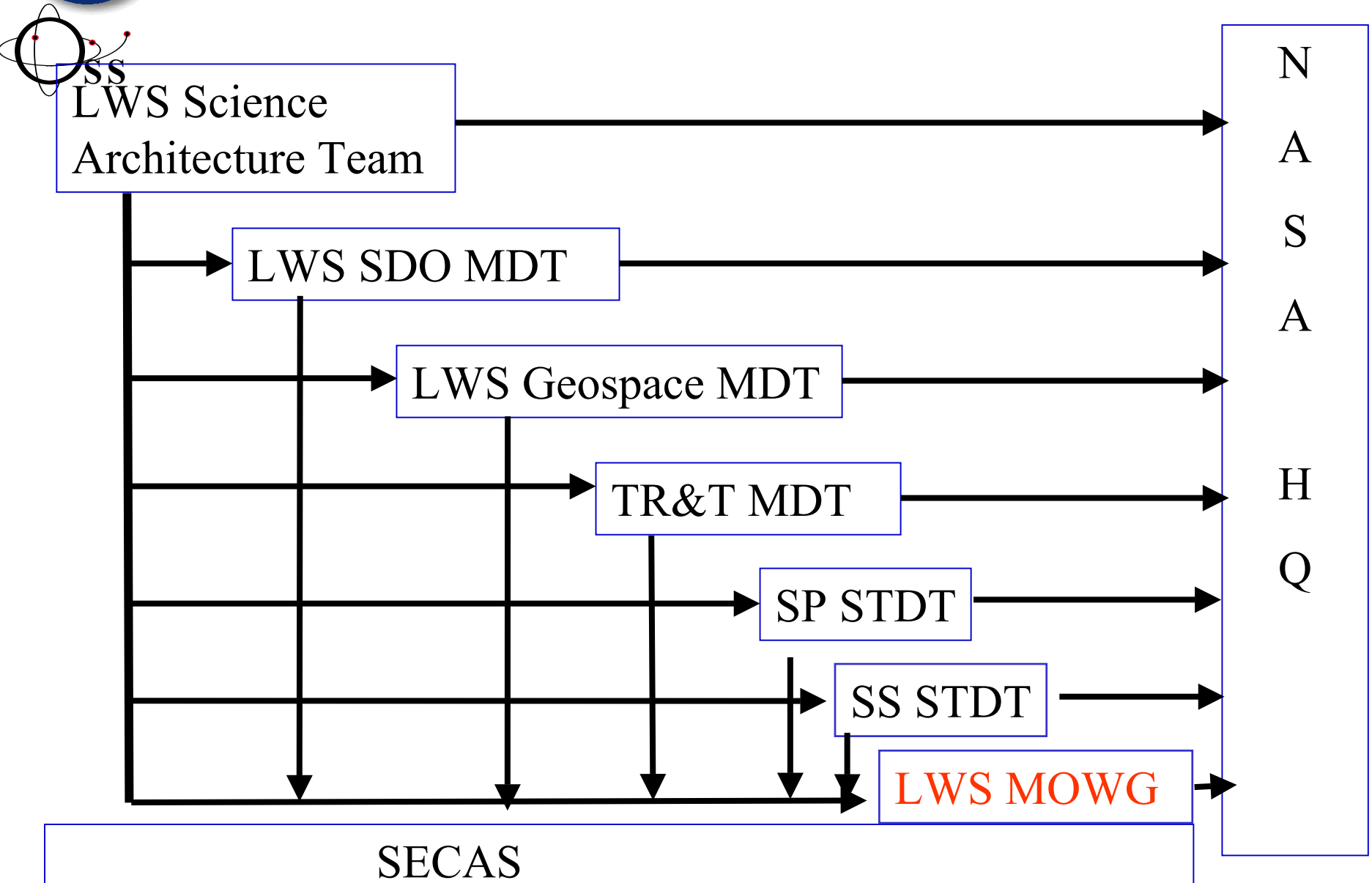


**LWS:** *Develop the scientific understanding necessary to effectively address those aspects of the connected Sun-Earth system that directly affect **life** and **society**.*

- **Solar Dynamics Observatory**  
SDO Confirmation in June, 2004.
- **Geospace Missions**  
AO in the process of being developed.
- **Sentinels**
- Strategy panel report will be available in May. Definition team to start in late spring. A task group is formed to look at agency's need for prediction of radiation environment/space climate chaired by Golightly (report due in Summer, 2004).
- **Solar Probe Mission**  
Science Technology and Definition Team kick-off meeting took place on March 3-4, 2004, 2<sup>nd</sup> meeting on July 6-7, 2004.
- **Space Environment Testbeds**  
Looking for partners to ride. Early results from data mining effort are already in use by JWST engineers.
- **Targeted Research & Technology Program**  
TR&T Steering Committee formed. TR&T goals and priorities set by SC. (Report out in Spring of 2004). Sun climate task group report released during Fall AGU. Results of TR&T selection will be announced today.
- **Partnership at National and International Level**  
Update on ILWS, NOAA, DoD.

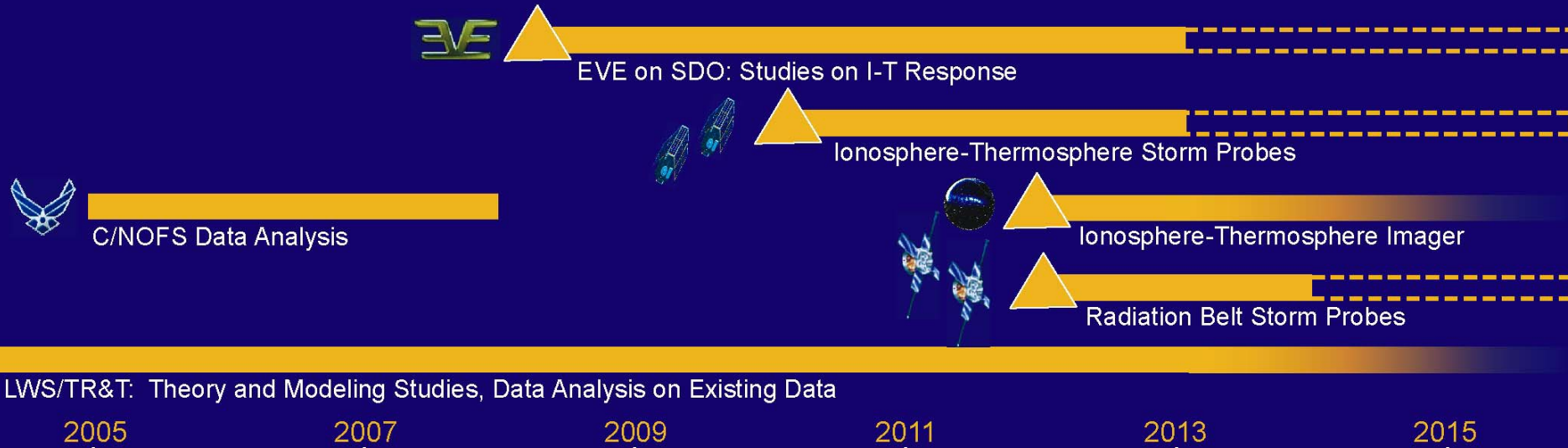


# LWS Science Planning





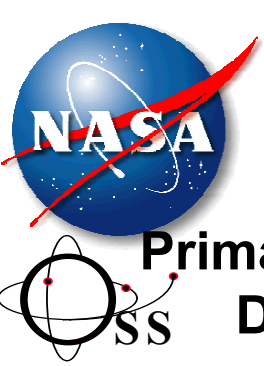
# Geospace Missions Status



## The status of the LWS/Geospace Missions remains as follows:

- We are presently in pre-formulation for the Geospace Core Missions (2-IT, 2-RB and an ionosphere-thermosphere imager (FUV) on a Mission of Opportunity).
- The Program office and Headquarters will continue to seek partners (both national and international) in order to reduce cost as well as advance the schedule.

Announcements of Opportunity are in preparation that reflect the above strategy.



# Sentinels Update

## Primary Objective:

**Discover, understand and model the connection between solar phenomena and its propagation through the heliosphere**

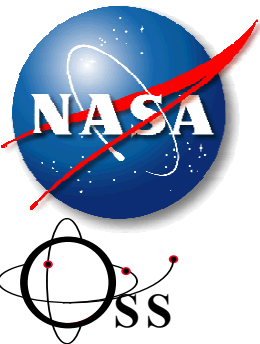
## Heliospheric Strategy Panel Charter:

- Identify heliospheric measurements required to make progress in LWS program objectives.
- Determine to what extent current and future assets could be used to contribute toward the LWS heliospheric objectives and make recommendations for improved utilization.
- Identify current and past mission data sets relevant for the LWS heliospheric objectives that are currently not publicly available and suggest possible solutions.

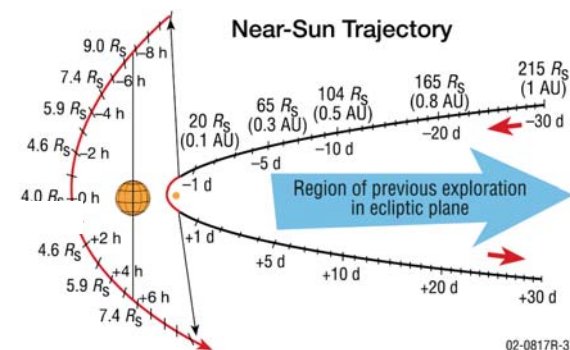
**Report due in Spring 2004**

## *Sentinels Status*

- **Mission architecture under study with International Living With a Star (ILWS) partners**
- **SDT to be formed in Spring of 2004**

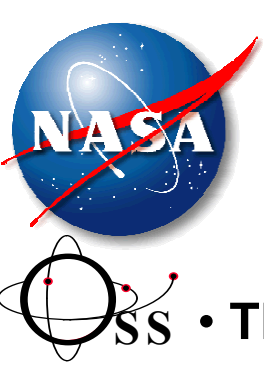


# Solar Probe Science & Technology DT Established



- A highly successful kick-off meeting of Solar Probe took place on March 3-4, 2004 at SWRI with Dave McComas as the chair. Next meeting at APL 6-7 July.
- The definition team consists of experienced international scientists and technologists.
- A report is expected within a year.





# Science Definition Team: Process

- The SEC Science community is represented by 20 members
- Received input from an open, community-wide (national and international) “news letter”
- Goal is to work closely with the Project to define mission characteristics and *Payload Accommodation Envelope*
- Identify a hierarchy of:

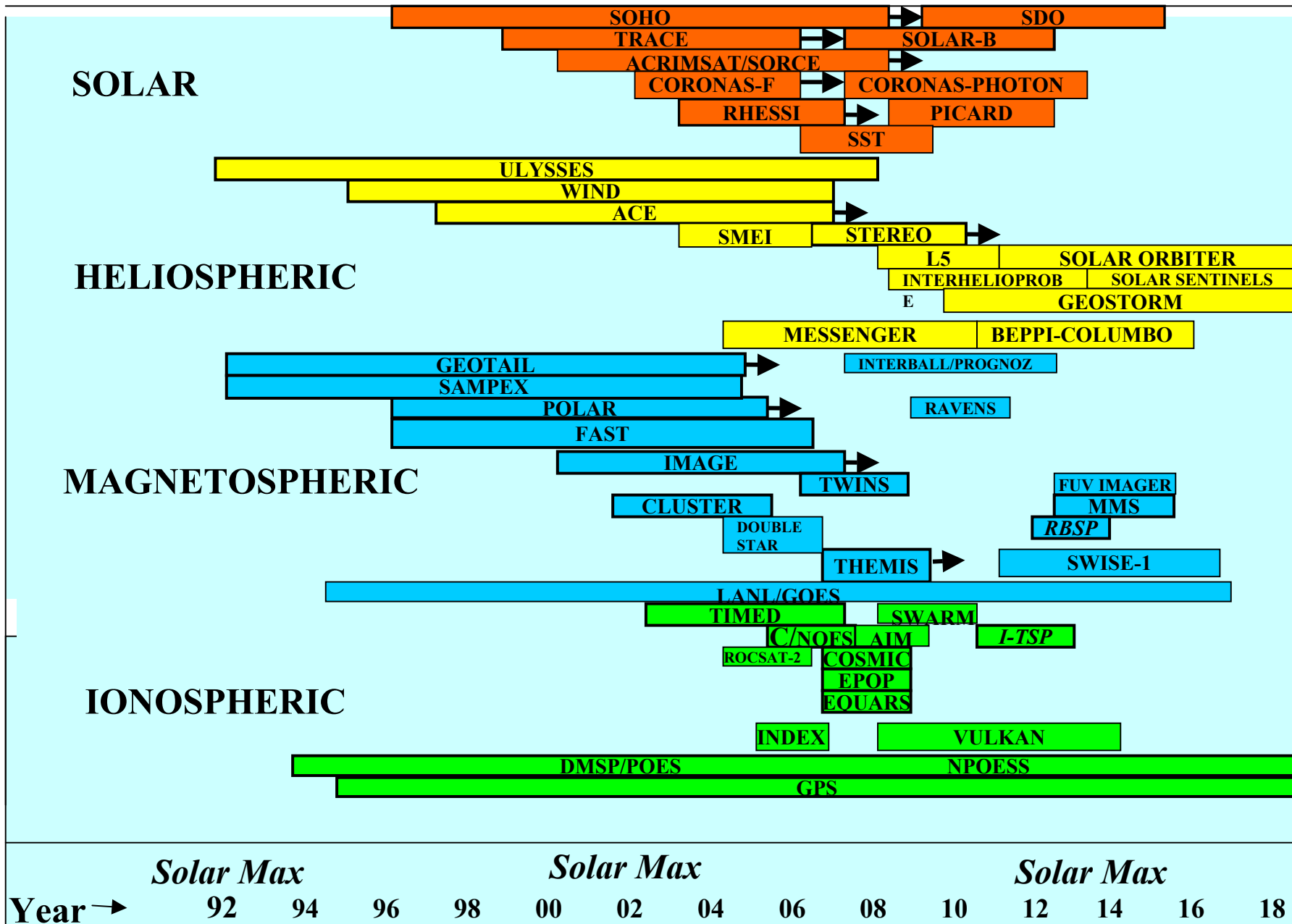
*Goals*

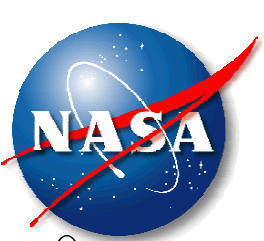
*Objectives*

*Investigations => measurement*

- Define priorities at the objectives, investigation and measurement level - define a scientific performance floor for the mission.

# LWS-Related Missions



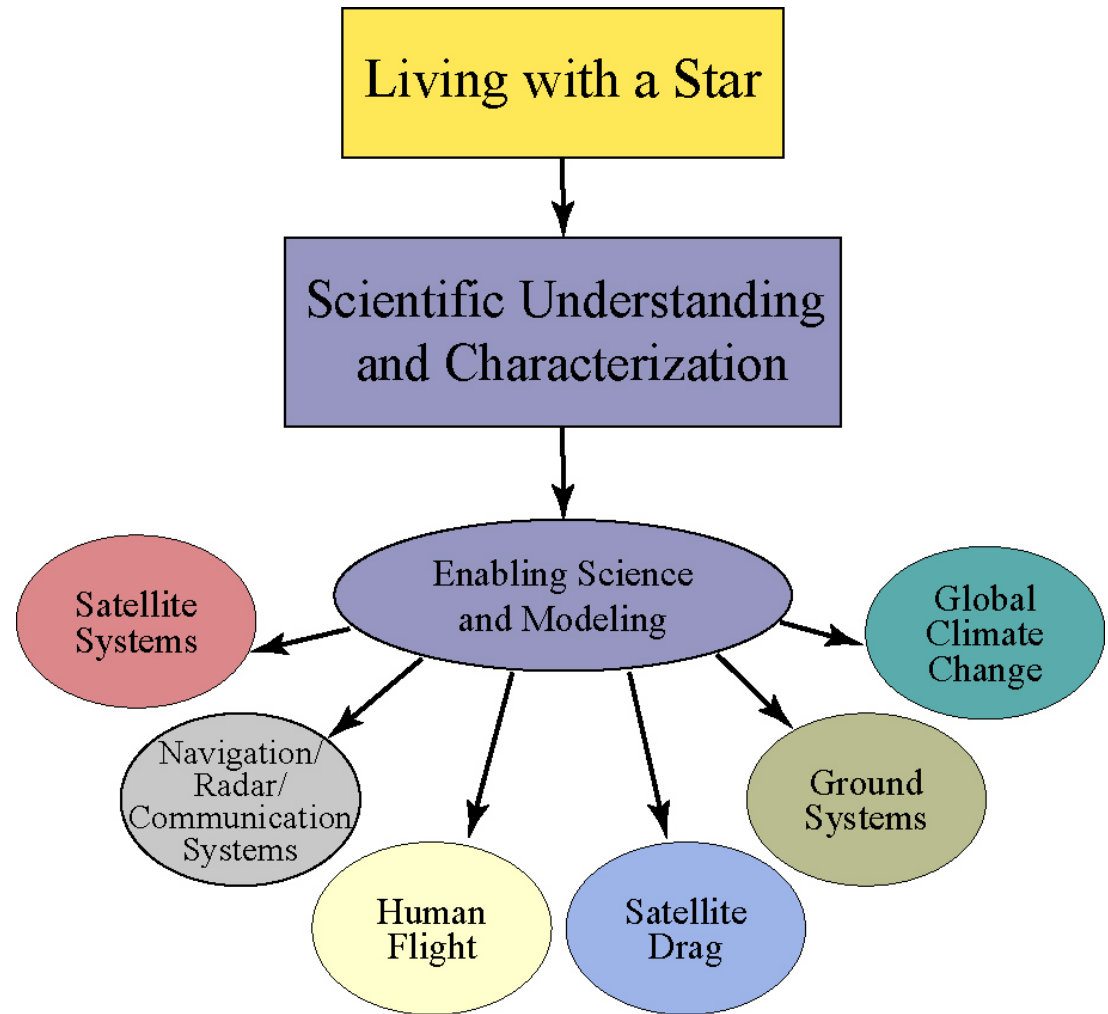


## Science Application as the Focus



The primary goal of the LWS Program is to develop the understanding necessary to enable the U.S. to effectively address those aspects of the Connected Sun-Solar system that directly affect life and society.

- Space Weather
- Space Climate
- Sun-Climate Connection







## **Research Priorities Based on Report Targeted Research and Technology Science Definition Team**

### **Research Topics:**

#### **1.0 Effect of Solar Variability on Terrestrial Global Climate Change**

**1.1 Sun-Climate relationship**

**1.2 Stratospheric ozone change**

#### **2.0 Space Weather**

**2.1 Background ionosphere**

**2.2 Ionospheric scintillations**

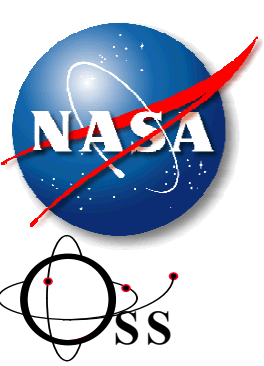
**2.3 Density and composition of the neutral thermosphere**

**2.4 Geomagnetically-induced currents**

**2.5 Energetic particle environment in the magnetosphere**

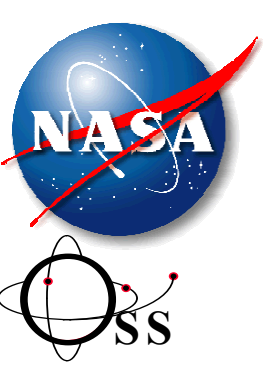
**2.6 Radiation associated with explosive events on the Sun**

**2.7 Radiation from Galactic Cosmic Rays\***



# LWS TR&T Update

- **HQ used TR&T SDT (Gosling) report to modify and focus 2003 NRA objectives**
- **Large increase in proposals (187) combined with decrease in funding (4.25 M--> a diminished success rate for TR&T this year (1/4.6)**
- **Two-full days of TR&T presentations at Fall AGU**
- **Selection of 2003 proposals will be announced today**
- **TR&T Steering Committee met on 3/30-3/31/04. Report available on the web.**
- **Revised NRA for ROSS 2005 will be posted before June 20<sup>th</sup>, 2004.**



# **LWS Outreach Activities**

- An exhibit on TR&T and Sun-climate components of the LWS program was presented at the AGU Fall meeting, 2004.**
- LWS and ILWS was presented at the American Meteorological Society's meeting in January 2004 with an SEC/LWS booth.**
- International Living With a Star led by NASA was a one year agenda item at the UN Scientific and Technical Subcommittee meeting of the Committee on Peaceful use of Outer Space. It was a big success with 8 countries presenting material on ILWS initiative and expressed strong endorsement to this new initiative. NASA and ESA jointly hosted an ILWS booth at the UN hall.**
- A one year agenda item has now been submitted to this committee on International Heliospheric & Geophysical Year 2007.**



# Summary of LWS Workshop (23-26 March 2004)

Over 180 scientists attended the 4-day LWS workshop in Boulder, Colorado in March 2004 to discuss the missions, measurements, and models being developed for the NASA Living With a Star (LWS) program.

**Session 1** included 5 talks about the SDO mission and its three solar instruments, a talk about the GSFC community models, a talk about the STEREO mission, and 10 poster papers. The SDO mission is the first one for the LWS program, and its launch is planned for 2008. The SDO program will complement the STEREO program whose primary goal is the study of CMEs. The measurements of the solar EUV images, solar EUV irradiance, and vector magnetograms will be made by the SDO instruments AIA, EVE, and HMI, respectively. These SDO measurements will be made continuously and with high time cadence for new types of science research and will be used for space weather operations and forecasting.

**Session 2** had 10 talks and 14 posters that included presentations about the GOES solar EUV measurements, the French PICARD mission, solar irradiance measurements, and modeling the solar radiation, corona, and CMEs.

**Session 3** had 10 talks and 9 posters that discussed the measured and modeled response of the Earth's upper atmosphere, ionosphere, and magnetosphere to the highly variable solar changes.

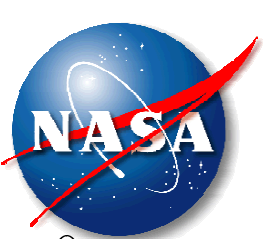


# Summary of LWS Workshop (23-26 March 2004)

**Session 4** had 9 talks and 22 posters that presented the recent studies of solar phenomena such as magnetic field evolution and the October-November 2004 solar storms when record-breaking flares and CMEs occurred. This session included results from SOHO and TRACE and information about the SOLAR-B mission and instruments.

**Session 5** had 7 talks and 12 posters that explored the understanding of the solar dynamo mechanisms and sub-photosphere dynamics (flows).

**Session 6** had 6 talks and 12 posters that discussed the solar wind effects from the Sun, through the heliosphere, and into the Earth environment.



## 2004 Huntsville Modeling Workshop



### Challenges in modeling the Sun-Earth System

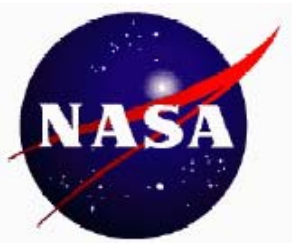
To advance the modeling of the coupled Sun-Earth System

**October 18-22, 2004**

Huntsville Hilton, Huntsville, Alabama

Conveners: S. T. Wu UAH/CSPAR  
& Jim Spann NASA/NSSTC

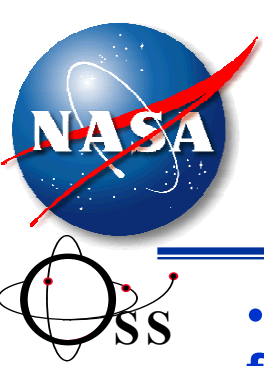
<http://science.nasa.gov/HSVWorkshop/>



**UAH**

**CSPAR**

*A Living with a Star Workshop*



# Sun-Climate Connection

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- **Report on Sun-Climate DT presenting a well-reasoned foundation and priority goals for the study of possible solar influences on climate is now complete and available in paper copy as well as on CD.**
- **Task Group Chaired by Jack Eddy met in June 2003**
  - **Charter is to develop a comprehensive intellectual foundation for the scientific investigation of the influence of solar variability on climate, and through this process, to help refine the focus and definition of the Sun-Climate component of the NASA LWS Program**
- **Goals**
  - **to assess the current state of Sun-Climate science and associated uncertainties**
  - **to identify high priority questions for future research**
  - **to identify opportunities for progress in the next five years and the next decade**
  - **to outline the essentials of a viable Sun-Climate research effort**

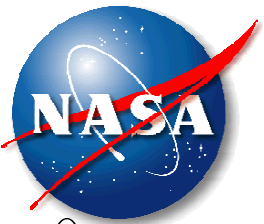


**HST- Explorer**

# **Response to Findings**

- **Loss of SDO Coronagraph**
- **ILWS Collaborative Approach Reconvening GMDT**
- **LWS Cost Growth & Need for Simultaneity**
- **A Revitalized LWS Program Plan**
- **Fy04/05 Budget Cuts/Implications & Earmarks**
- **Clarifying Scope of ILWS**
- **Mission Gaps**
- **Events have been overtaken by Exploration Initiative. Two SEC Explorer missions have been confirmed in April, 2004**
- **Eurocor gained and lost (chart follows)**
- **Done (chart follows)**
- **Topic for this meeting**
- **Topic for this meeting**
- **Addressed at AGU Agency Night**
- **Done**
- **Looking at all options**

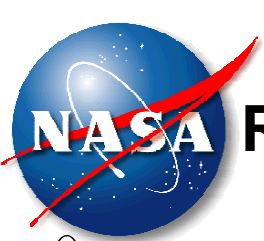




# Response to Findings (cont.)



- **Heliospheric Science Planning**
- **Solar Sentinels Science & Technology Definition Team about to be formed. Strategy Panel Report will be presented by Adam Szabo**
- **TR&T Steering Committee**
- **SC report will be presented by Spiro Antiochos**
- **Secondary Ride on SDO**
- **Still available**



# Returning Coronagraph Capability to the LWS Program



In March NASA Headquarters received a letter from ESA, proposing a European consortium to provide a coronagraph for SDO , Eurocor.

- Considering the tight schedule, ESA is proposing a coronagraphic design that is very classical, with strong heritage from the successful LASCO C2 and STEREO COR2 instruments.
- New plan appeared to have reasonable funding, expertise and consortium structure with ASI as the lead institute.
- ESA was willing to act as the guarantor
- However, evaluation of this proposal by the GSFC project office estimated the schedule to be short by 18-24 months.
- As a consequence NASA and ESA jointly decided not to pursue this option for SDO right now.
- **HQ will continue to look for opportunities for a coronagraph**



# SWARM/GMDT

**The GMDT were asked to consider the following points.**

- 1. Assess the adequacy of the current Core mission launch dates, particularly with respect to solar drivers.**
- 2. Identify and evaluate the benefits of an “original payload” SWARM trade-off with the GEOSPACE missions to LWS/Geospace science.**
- 3. Identify measurements which require mission simultaneity, considering all available assets, rather than LWS in isolation.**
- 4. Evaluate the impact on Geospace science if unforeseen circumstances eliminate availability of SWARM data.**

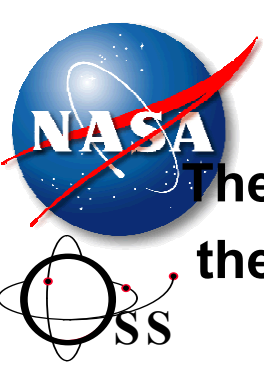
**The launch dates presented to the GMDT for consideration were:**

- 1. Geospace Core mission without SWARM**
  - a. ITSP spacecraft 3/2010-9/2010**
  - b. FUV imager 10/2010-4/2011**
  - c. RBSP spacecraft 3/2012-9/2012**

**Modified Geospace mission with SWARM wherein the RBSP spacecraft and FUV imager are unchanged, only one ITSP spacecraft is launched, and the SWARM spacecraft includes the addition of one EFI instrument on each of the four SWARM spacecraft**

- a. ITSP spacecraft 1/2010-7/2010**
- b. FUV imager 10/2010-4/2011**
- c. RBSP spacecraft 1/2012-6/2012**
- d. SWARM EFI 1/2009-6/2009**

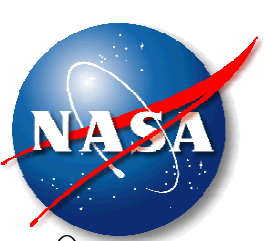
**The GMDT further acknowledges that the SWARM project would be willing to consider the addition of a neutral wind/density instrument in place of (or in addition to) an accelerometer. The SWARM project additionally expressed an interest in launching SWARM as soon as possible, perhaps as early as 2007 or 2008 in order to maintain continuity of measurements with the CHAMP project.**




# GMDT Findings

**The GMDT first considered the proposed launch schedule of the Core mission without SWARM and reached two conclusions**

- 1. If the ITSP spacecraft and FUV imager are not launched before the next solar maximum, they will not be able to make measurements when the EUV flux from the sun is a maximum and when the ionosphere reaches maximum density. Because the most significant societal impact of the ionosphere occurs at maximum density, the GMDT concluded that the dates noted above are perilously close to solar maximum and every effort should be made to assure that there is no further delay. This point is essential for all of the goals of section 2.3 of the GMDT report (Ionospheric-Thermospheric Variability) and absolutely critical for goal 2.3.5 (What are the Space-Weather Effects of Ionospheric Variability at Mid-Latitudes?).**
- 2. Among the priority radiation belt science goals defined by the GMDT are the investigation of the creation and energization of outer zone electrons by high-speed solar streams, during magnetic storms, and changes in the radiation belts produced by shocks propagating in the solar wind (for example see section 2.2.1 of the GMDT report, Which Physical Processes Produce Radiation Belt Enhancement Events?). These phenomena reach a maximum in intensity and rate a few years after solar maximum. Hence the 2012 launch dates for the RBSP spacecraft are also perilously close to the period of optimum science and every effort should be made to assure that there is no further delay.**

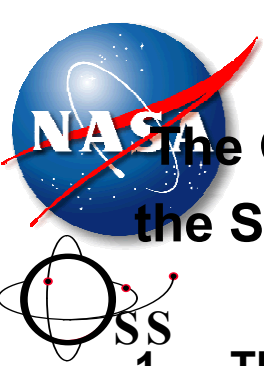


# **GMDT Findings (cont.)**

The GMDT also considered the advantages of teaming with the SWARM mission and found the following advantages.

- 1. SWARM may be launched earlier (2007-2009) and is likely to be active near solar maximum.**
- 2. SWARM is likely to have an operational period overlapping the SDO mission and would benefit from data acquired by the EUV instrument.**
- 3. The high inclination orbit of SWARM with the magnetometer and EFI instruments will yield energy input into the auroral regions.**
- 4. The four spacecraft in multiple orbits will, by themselves, yield better local time coverage and will also yield gradients in the meridional direction.**

**The GMDT concluded that items 1, 2, and 3 were significant although The auroral regions are not a priority goal of the Geospace missions. Item 4 was thought to be less significant because the DMSP/NPOESS missions will yield similar orbital coverage as SWARM.**

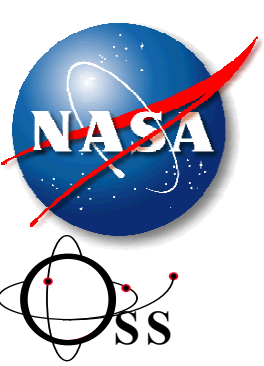


# **GMDT Findings (cont.)**

**The GMDT also considered the disadvantages of teaming with the SWARM mission and found the following disadvantages.**

- 1. The SWARM orbit is not optimal for mid-latitude investigations. No zonal gradients will be measured and certainly no zonal gradient at two latitudes will be measured.**
- 2. If SWARM is too early, it will not overlap the remaining ITSP spacecraft and FUV imager. At least two years of overlap are required for a sensible data set.**
- 3. The Geospace program would lose coordinated spacing between simultaneous spacecraft and the ability to investigate spatially confined and time varying I-T features.**
- 4. Vector neutral winds will not be measured on two spacecraft although this could possibly be corrected by inclusion of a neutral wind instrument on the lower two SWARM spacecraft (450 km).**
- 5. Investigation of ionospheric irregularities and scintillations are not included in the SWARM system design. This could possibly be corrected with faster data links and increased data volumes.**
- 6. SWARM does not have neutral mass composition measurements implying loss of ability to calculate local recombination rates. This omission takes on added importance if there is no overlap with the FUV imager.**

**In noting these disadvantages the GMDT concluded that items 1-5 were critical to the success of the Geospace science goals. Item 6 is significant to the success of the Geospace science goals and becomes critical if there is no overlap with the FUV imager.**



# GMDT Findings (cont.)

**In summary the disadvantages of teaming with the SWARM mission outweigh the advantages. The cost savings of teaming with the SWARM mission were consistent with this conclusion. The cost studies presented to the GMDT indicated that the savings created by including an EFI instrument on the SWARM spacecraft and deleting one ITSP-LEO spacecraft were much less than the estimated overrun of the allotted budget by the Ionospheric-Thermospheric investigations. The small budget relief does not compensate for the loss of several core measurements targeted at mid-latitudes.**



# LWS & Exploration

**Radiation effects will be a significant part of any space exploration program.**

**There are three main areas where LWS might contribute**

## **Manned space flight**

***The biggest risk is in interplanetary space (or Lunar surface) from SEPs (Solar energetic particles)***

There is also significant risk from the terrestrial radiation belts (and south atlantic anomaly if travel to the moon or Mars is staged and starts with a stay in LEO (e.g. at the international space station or similar facility))

## **Planetary exploration**

If we want to understand the radiation environments at other planets and predict the potential effects there then we need to use the Earth's radiation belts as a local laboratory. Among the questions are:

What do we expect at other planets?

How do we scale what we observe if we don't understand the dynamics

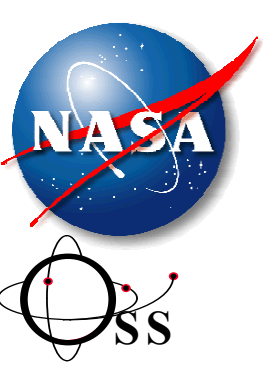
## **Space Infrastructure**

Understanding the impacts of the Earth's radiation environment on space infrastructure will be increasingly important as mankind moves even more aggressively into space.

Space infrastructure will have to increase and will be vulnerable to radiation belt effects

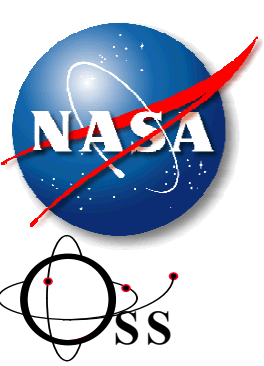
Space exploration is not completely uncoupled from the increasing DOD programs in Military Space, Space Control, and Space Situational Awareness. Geospace missions have increasing relevance to those important national programs.





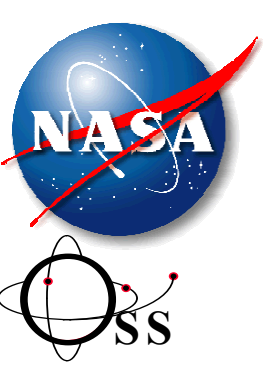
# LWS & Exploration

1. Identify the broad space weather/space climate needs of NASA Exploration Vision, especially for the future directions our Agency will be taking. This includes technology development, scientific research and understanding, and the concerns regarding the effect of space weather/space climate phenomena on a long-term human presence in space.
2. Identify the assets, programs, and development efforts that NASA has or has access to, now and in the future, which can be used to further our ability to understand space weather/spaceclimate and its effects on Exploration.



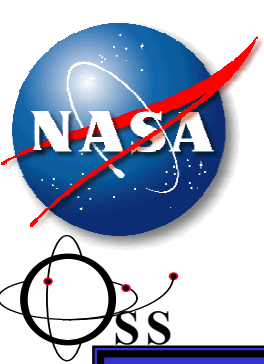
# LWS & Exploration (cont.)

- 1) Near-term: e.g. assets which can be readily adapted to fit more of NASA's space weather needs. Missions currently taking measurements (SOHO, ACE, Ulysses), missions which can be mobilized for space weather usage with minimal effort (Cassini and other planetary programs), models which can be easily implemented, and modifying observing and reporting structures to suit the broader needs of NASA.
- 2) Intermediate term: e.g. focus on technology development, such as radiation-hard components, which will allow us more independence and reliability in space; focus on gathering more information regarding the exposure and effects of exposure of various types of radiation on humans.
- 3) Long-term: e.g. identifying current plans and roadmaps which can be synergized to better suit NASA's needs.



# The Greatest Single Challenge to LWS is to Improve Our Ability to Forecast Solar Particle Events

- While significantly lower in energy than the GCR, the proton flux of SPEs is orders of magnitude greater for hours to days
- Principle of ALARA requires that exposure to SPEs be minimized
- Potential to be caught away from shelter on the Lunar or Martian surface will impose operational rules that will limit flexibility and reduce efficiency



# Forecasting SPE is a Multidiscipline Challenge

Predict the eruption  
of a CME



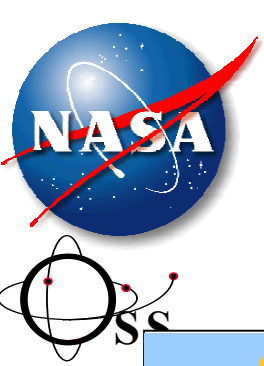
Predict the  
character of the  
CME



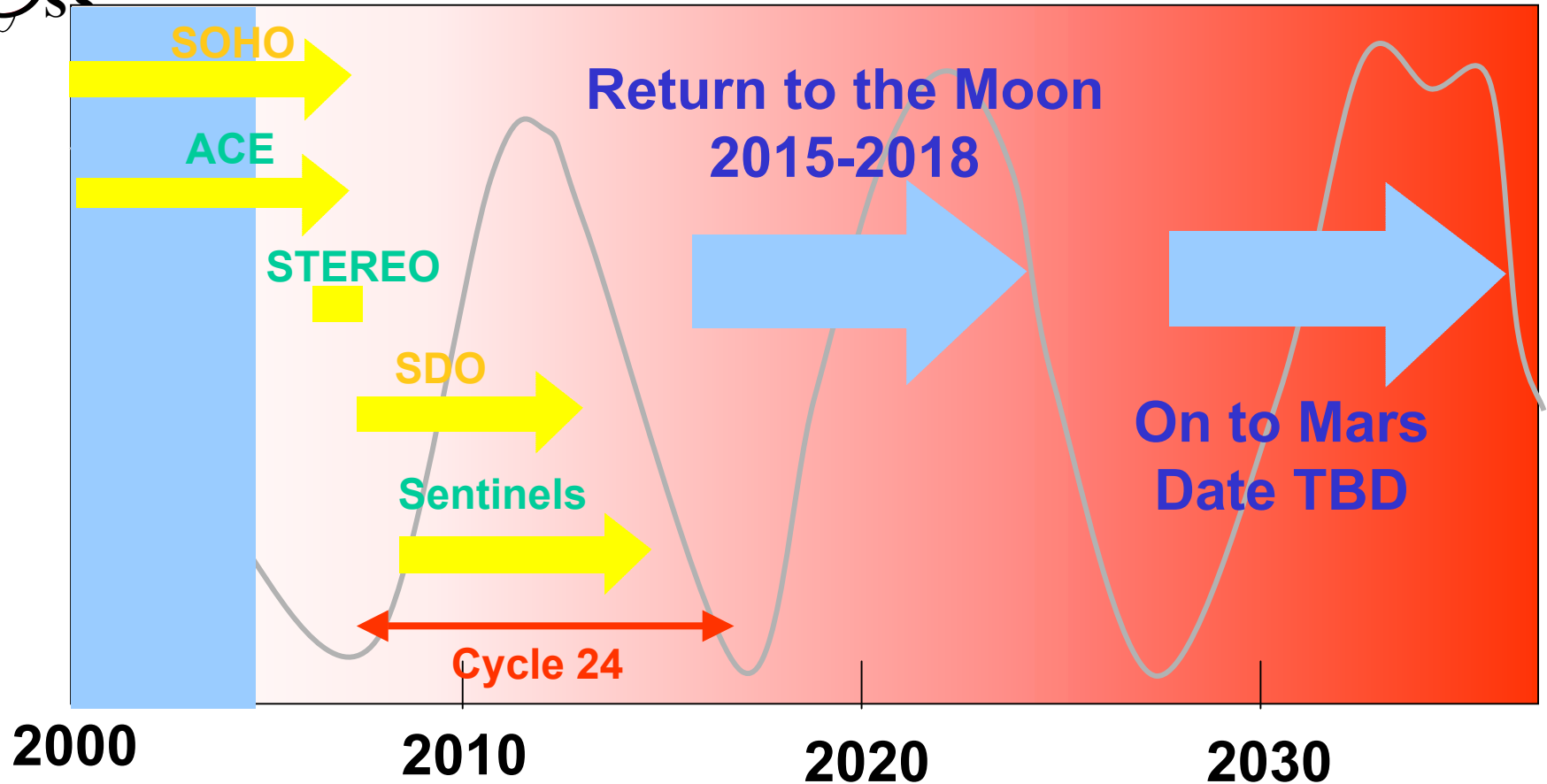
Predict the efficiency of the  
CME to accelerate particles



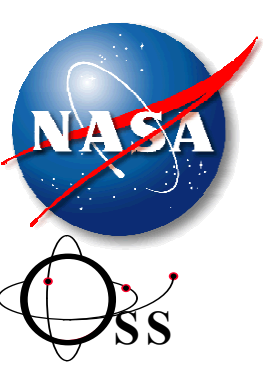
Predict the particle  
escape from shock and  
subsequent transport  
through heliosphere



# Significant Events in the Moon, Mars, and Beyond Vision



Only One More Solar Cycle Left to Learn What We Must Learn



# Solar Observing/Monitoring

**Routine solar observation is the necessary first step to forecast and characterize of SPEs**

**Near-real-time observations of solar active regions and emerging Coronal Mass Ejections (CMEs) may provide data useful to forecast the progress of an on-going SPE over a period of hours to days**

**Additional progress in understanding the physics of CMEs may lead to a multiday forecast of the probability of an SPE**

**LWS Solar Dynamics Observatory and the Sun-Earth Connections STEREO Mission can build on the current suite of research spacecraft and ground-based facilities to select the appropriate operational instruments for solar monitoring**



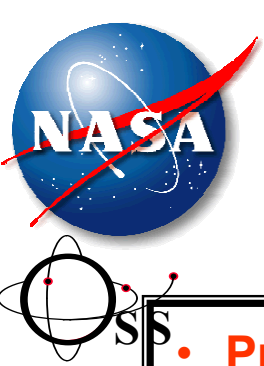
# Heliospheric Monitoring

**Heliospheric observations provide information necessary to model or monitor the propagation of solar energetic particles from the source to the astronauts**

**The data that may be necessary for SPE propagation models include**

- **State of the ambient solar wind plasma**
- **Interplanetary magnetic field**
- **Local disturbances moving through the inner heliosphere**

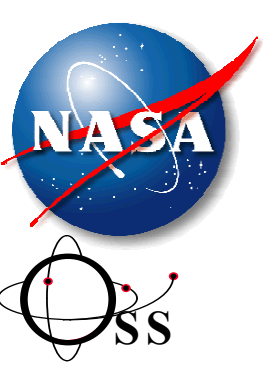
**LWS Sentinel Missions will provide experience and proof of concept from which we will be able to learn more about the underlying physics and select the appropriate operational instruments for solar monitoring**



# What We Must Know About Solar Particle Events to Reduce the Risk to Astronauts

- **Priority 1 Critical Question** *What are the risks from SPE's and what is their impact on operations, EVAs and surface exploration?*
- For astronaut radiation safety, the important SPE energy range is **from 30 MeV up to 100-200 MeV**
  - Spectral slope is very important
- **SPE forecast goal according to findings of 1996 SPE risk mitigation workshop is**
  - 10 to 12 hour forecast prior to a likely event
  - 6 to 8 hour forecast of magnitude and spectral slope after event on-set
  - 3 to 4 hour rolling forecast as SPE progresses
- **Realistic near-term challenge:**
  - 8 hour rolling forecast as SPE progresses
  - Predict, at event on-set, the time of arrival and magnitude of shock-enhanced peak
  - **Reliably forecast 3 to 7 day "all clear"**





# How Can LWS Science Support the Moon, Mars, and Beyond Vision

## Better understanding of Solar Dynamics

- Improved Forecasting of Coronal Mass Ejections
  - Improved forecasting of SPEs

## Better understanding of Heliospheric Dynamics

- Improved Forecasting of Solar Wind profiles
  - Improved forecasting of SPEs

## Better understanding of SPEs

- Improved design of habitats and shelters
- Higher confidence in mission planning

## Better forecasts of SPE evolution after on-set

- Higher confidence in exposure forecast
  - Implementation of more flexible flight rules
- Reduced period of uncertainty
  - Greater EVA scheduling flexibility
  - Less down-time of susceptible electronics

## Prediction of SPEs before on-set

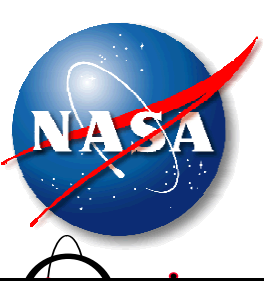
- Higher confidence in exposure forecast
  - Greater mission schedule assurance
  - Less down-time of susceptible electronics

## Prediction of “all clear” periods

- Higher confidence in exposure forecast
  - Greater EVA scheduling flexibility
  - Greater mission schedule assurance

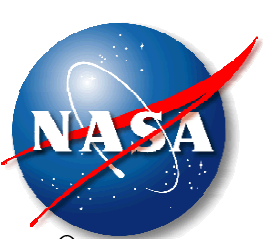


**Improved Safety and Enhanced Mission Assurance**



# Parallels Between Terrestrial and Space Weather—A User Perspective

	Terrestrial Weather	Space Weather
Time scale	Hours - ~ 2 days	Days to weeks
Spatial scale	Local – regional	Global
Use alerts and warnings?	Yes	Yes
Use nowcasts?	?	Yes
Use forecasts?	Yes	Yes
Forecast accuracy	Moderate-to-High	Low-to-Moderate
Use numerical data?	?	Yes
Use imagery?	Yes	Yes
Use vendor-supplied products?	Yes	No
Use user-developed products?	Yes	Yes
Use numeric data to drive user-developed models?	?	Yes
User operated monitoring equipment?	?	Yes
Endanger human health/safety?	Yes	Yes
Alter path to avoid weather?	Yes (depending on specific user)	No
Delay activities to avoid weather?	Yes (depending on specific user)	No, except for EVAs
Take shelter to avoid weather?	Yes	Yes
Can shelter completely eliminate risk?	Yes	No
Evacuate to avoid weather?	Yes	Not always



# Space Weather vs. Climatology—What's the Difference?

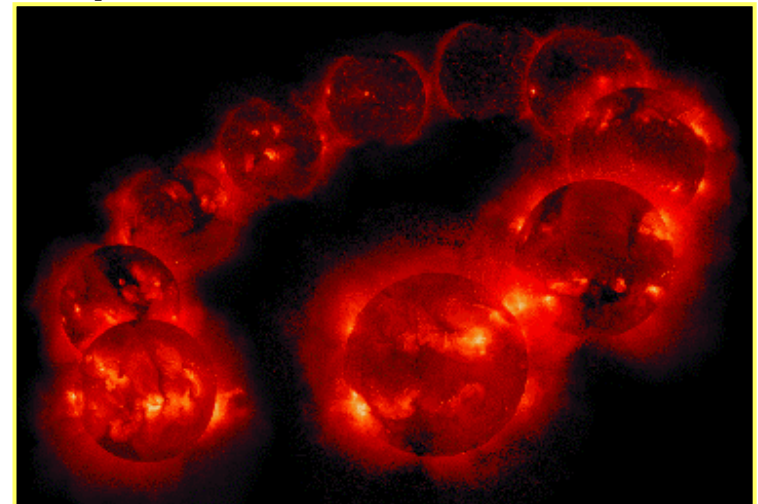
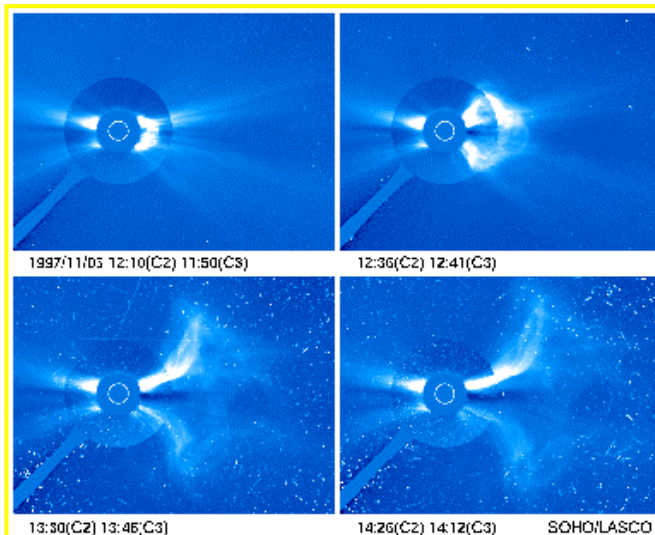
## Definition/ Characteristics

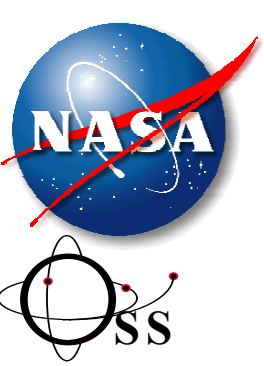
### Space Weather

- Transient events/short-term changes
- Individual event occurrence is stochastic but frequency distribution follows general climatological cycles
- Changes in parameter magnitude stochastic

### Space Climatology

- Long-term cyclic changes (11y, 22y, 88y, . . .) related to changes in overall level of solar activity
- Occurrence relatively predictable
- Changes in parameter magnitude relatively predictable





# **Space Weather vs. Climatology— *Do they have different sources/causes?***

<b>Source/ Cause</b>	<b><u>Space Weather</u></b>	<b><u>Space Climatology</u></b>
	<ul style="list-style-type: none"><li>• <b>Sun</b></li><li>• <b>“Explosive” mass and electromagnetic energy release</b></li><li>• <b>Solar wind velocity and density variations</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Sun</b></li><li>• <b>Solar wind velocity and density variations</b></li><li>• <b>EUV emission variation</b></li><li>• <b>Global solar magnetic field orientation</b></li></ul>



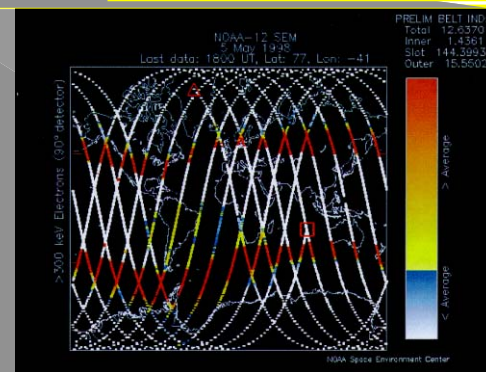
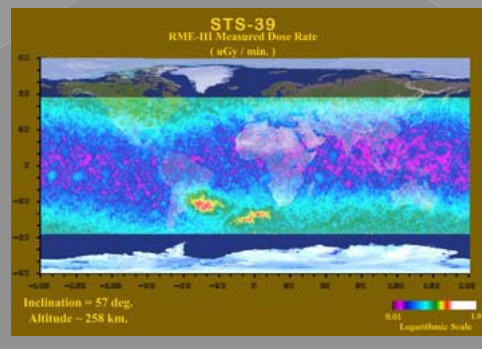
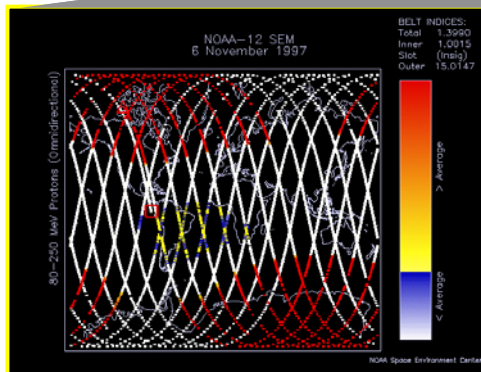
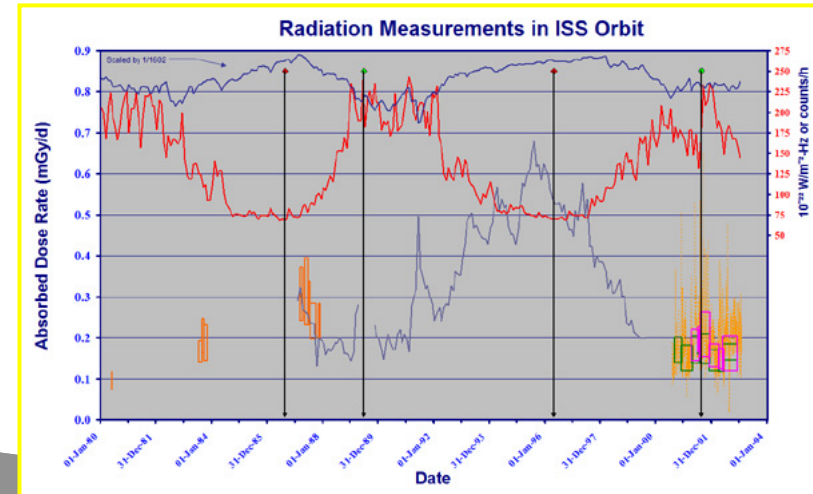
# Space Weather vs. Climatology—*What are the Impacts?*

## Space Weather

- 4 to 6 orders of magnitude increase in near-Earth proton flux
- Factor of 2 to ~100 increase in outer belt electron flux
- Decreased geomagnetic shielding (shielding against interplanetary charged particles)
- Additional trapped radiation belts

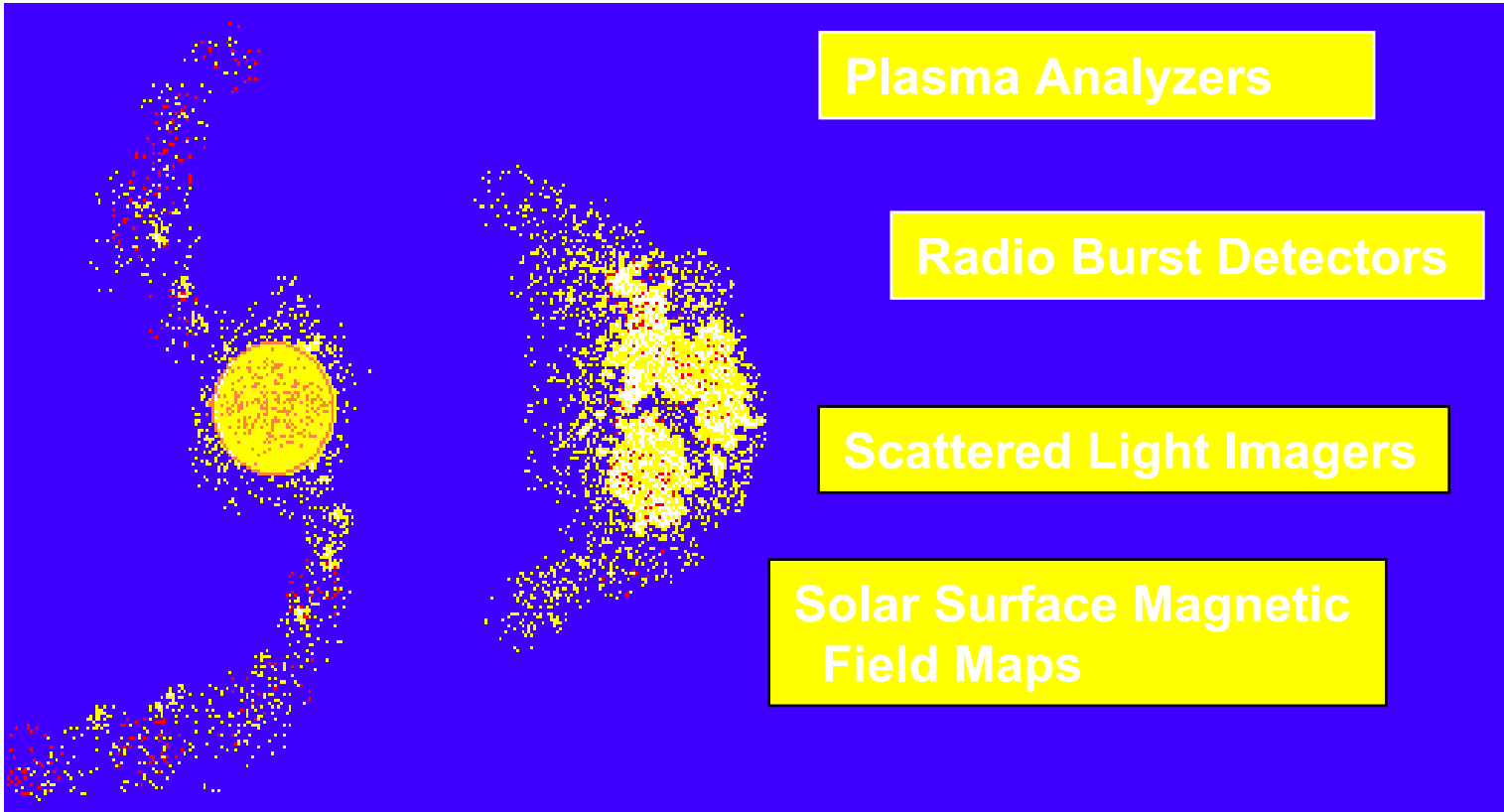
## Space Climatology

- Factor of 2 to 3 modulation in GCR flux
- Factor of 2 modulation in trapped proton flux

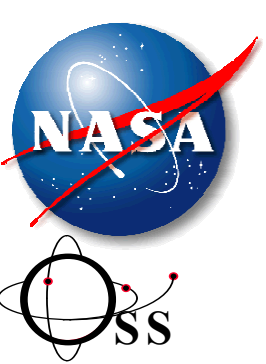




# Heliospheric Monitoring (continued)



**A Variety of Tools are Potentially Available to Help Characterize the Heliosphere**



**END**